(English Translation)

# Refinements made to X-ray tube arrangements

The present invention deals with X-ray tube arrangements, and it relates in particular, although not exclusively, to such arrangements with a view to use in a tomographic appliance equipped with a computer.

The aim of a tomographic appliance equipped with a computer is to provide a representation of a feature of a body, related to the penetrating radiation, at numerous points distributed over a cross-sectional slice of the body. Examples of tomographic appliance equipped with a computer are described in the French patent No. 69/29050; it will be observed that, in order to provide the required representation, the penetrating radiation (usually an X-ray) is projected through the slice of the body along numerous narrow beam paths, some of which intersect inside the body, and the quantity of radiation emerging from the body along each path is detected. This makes it possible to evaluate the linear integral of the absorption undergone by the radiation on travelling each beam path, and these absorption linear integral values, called marginal values, are processed to evaluate the absorption coefficient, relative to the penetrating radiation used, at each of numerous points distributed over the abovementioned slice.

Such an appliance has proved useful in studying living human bodies for medical diagnosis purposes. However, when certain parts of the human body, such as the chest, need to be examined, movements of the body can provoke an error in the marginal values, thus provoking inaccuracies in the representation.

One of the aims of the present invention is to produce an X-ray tube arrangement which, if used in a

tomographic appliance equipped with a computer, makes it possible for the necessary marginal values to be rapidly collected, thus reducing the effect of the movements mentioned in the preceding paragraph.

According to the invention, there is provided an X-ray tube arrangement comprising a target sending elongate X-rays which is curved around an axis and subtends a major angle on said axis, a source of at least one electron beam, means for making said beam strike a region of said target so as to make the latter emit X-rays in the general direction of said axis, and means for making said beam emanate from source positions distributed along said target to provoke an emission of X-rays, in said general direction, from different regions along said target.

In order for the invention to be able to be clearly understood and easily implemented, some of its embodiments will now be described, purely by way of example, with reference to the appended drawings.

- Figure 1 represents, in plan view, a part of an arrangement according to an example of the invention.
- Figure 2 represents a cross section according to the arrows II-II of the arrangement represented in Figure 1.
- Figure 3 represents, also in cross section, another arrangement similar to that represented in Figures 1 and 2.
- Figure 4 represents, in lateral elevation and partial cross section, a tomographic analysis appliance equipped with a computer incorporating the arrangement represented in Figure 3.
- Figure 5 represents, in cross section, an arrangement similar to that represented in Figures 1 and 2, but which uses an anode that is transparent to the X-rays.

- Figures 6 to 10 represent, in cross section, arrangements according to other embodiments of the invention.
- Figure 11 represents, in schematic form, a selector circuit device for use with the arrangement represented in Figure 10.

Reference is now made to Figures 1 and 2, in which an annular X-ray tube 1 contains an elongate anode 2 which is curved around an axis 3. The X-radiation emitted from the anode 2 is projected in the general direction of the axis 3, in a plane defined by a tapered collimator 4 which is fixed to a ring 5 which forms a part of the envelope of the tube 1.

The ring 5 is made with a lead coating 6 over its internal surface to absorb the radiation emitted from the anode 2 in directions other than that defined by the collimator 4. The envelope of the tube 1 can be made in three parts which are hermetically welded or fixed differently to each other, the three parts comprising an annular groove 7, the ring 5 and a disc 8. The ring 5 is hermetically fixed to the groove 7 such as at 9; the ring 5 is fixed hermetically to the disc 8 such as at 10 and the groove 7 is fixed hermetically to the disc 8 such as at 11.

The X-ray emitting target 2 comprises a tungsten element placed in an annular copper anode 12 which is fixed to the disc 8. Positioned inside the tube 1, there is a bearing race formed by profiling inside the groove 7 and an annularly-positioned rail 14 which is supported by columns, such as 15, rising up from the base of the groove 7. A cathode 16 made, for example, of rolled tungsten, is mounted on a carriage 17 which is made with three wheels, two of which can be seen at 18 and 19, intended to run on the bearing race formed by the components 13 and 14. The wheels can be pushed elastically in contact with the rails if that is

desired. Suspended from the carriage 17, there is a rotoric sensor 20 which cooperates with a statoric winding 21 positioned outside the envelope of the tube 1 to drive the carriage around the bearing race by electromagnetic induction in a known manner. Conveniently, the wheels 18 and 19 of the carriage can be used to collect the electrical power supplies needed to heat the cathode 16, via the rail 14 and the profiling 13 respectively; the profiling, naturally, being coated with an electrically conductive material such as copper. An electrical conductor 22 is represented, passing through the envelope of the tube at 23 and establishing an electrical contact with the rail 14. The conductor 22 is hermetically sealed to the envelope of the tube at 23. A similar connection (not represented) can be made to the conductive coating on the profiling 13, and the two duly made connections can route, via respective electrically conductive channels, represented by dotted lines at 24 and 25, the necessary heating current to the cathode 16 and also make it possible to establish its potential relative to the anode 2, 12. The carriage 17 is made of electrically insulating material (for example of enamelled ceramic) independently of the channels 24 and 25.

Rising up from the carriage 17, there is an upright 28 which supports a collimating paddle 27. Another upright and another collimating paddle are hidden behind the components 26 and 27; the paddles being close to one another on their edges 28 closest to the target/anode and diverging when they approach the ring 5 so as to define a radiation fan with an extent of approximately 15° in the plane defined by the collimating ring 4. Preferably, the distance between the cathode 16 and the anode 2, 12 must be substantially less than that between the edge of the paddle 28 and the anode 2, 12 so that electrical fields directing the electron beam 29 to the target are not disturbed by the presence of the paddle 27 or of the upright 26.

The radiation emitted from a given region of the target 2 when the cathode 16 is beneath it and, by virtue of an appropriate electrical field established between the anode and the cathode, an electron beam 29 of considerable intensity (for example 1 ampere per square centimetre) is directed to said region, is propagated through the collimating paddles such as 27 and the collimating ring 4 to a detecting array which is mounted on the top of the disc 8 by a support such as 30. A part of the detecting array is indicated at 31 and each detector comprises, for example, a scintillating crystal optically coupled either to a photoelectric electron-multiplier tube or to a photodiode. Positioned in the path of the radiation to the detector array, there is a static series (not represented) of collimators provided in a known manner to reduce the sensitivity of the detecting crystals to the radiation which is scattered by the body instead of being transmitted through the latter along substantially linear beam paths.

In operation, an appropriate potential is established between the target/anode 2, 12 and the cathode 16 and the carriage 17 is driven rapidly around the bearing race 13, 14 at a speed of approximately 600 revolutions per minute. Thus, the source of the electron beam 29 is displaced around the groove 7, making successive regions of the target 2 emit an X-radiation; the collimation performed by the paddles such as 27 and the ring 4 being such that it makes a fan-shaped spread of the radiation be displaced around the body and irradiate respective segments of the detector array.

In order to avoid the appearance of imbalance forces due to the rapid rotation of the carriage 17 and its accessories inside the envelope of the tube, a second carriage (not represented) can be constrained to be displaced on the bearing race 13, 14 and remain

diametrically opposite to the carriage 17. The second carriage is required to exert practically the same forces on the envelope as the carriage 17.

It should be noted that, in particular if the envelope of the tube is made of conductive material, appropriate insulating regions or supports must be provided to enable the necessary high potentials to be established.

A variant of the arrangement that has just been described will now be described with reference to Figures 3 and 4.

The tube 32 of Figure 3 is approximately 2 metres from one edge to the other and is made up of four parts of a gas-tight envelope, an internal cylindrical wall 33, an external cylindrical wall 34 and two similar terminal rings 35, 36. The four parts, which can be made of metal (such as stainless steel) or of glass fibres coated with copper on the inside to prevent a perfusion of the gases, are assembled in a hollow torus or tubular ring by hermetic fixing along raised edges. The internal wall 33 is made with a part 37 that is transparent to the X-rays, but is otherwise lined with lead around its internal surface. Appropriate forms of flange and sealing materials are known for producing such gas-tight envelopes. The envelope can be emptied via a coupling 38 to a vacuum pump system that is not represented in Figure 3. The envelope can be emptied until an appropriate vacuum is obtained and sealed or pumped continuously in use. The tube represented is pumped continuously.

The envelope comprises an anode 39, supported by the external cylindrical wall 34, and a cathode 40. Appropriate means are provided to support the high potentials needed between the anode 39 and the cathode 40. For this purpose, the wall 34 can be made of an appropriate insulating material for use in a powerful

vacuum or can be provided with an insulating internal wall. The cathode 40 is mounted on an annular carriage 41. The annular carriage is mounted on the external cylindrical wall 34 for continuous rotation, inside the torus formed by the envelope, around an axis 42. The support for the carriage comprises at least three skids angularly spaced uniformly around its circumference, and two of four such skids in the embodiment illustrated are represented as 43 and 44. The skids such as 43 and 44 pivot in a bearing 45 supported by the carriage. The skids are displaced in annular grooves 46 and 47, which can be formed between polytetrafluoroethylene flanges, around the inside of the external cylindrical wall 34. The carriage 41 can be driven around the inside of the tube by electromagnetic induction members such as the cooperating elements 48 and 49. Appropriate connections 50 for the element 48 pass through the envelope of the tube to excite the element and drive the carriage around the envelope of the tube. Other connections such as 51 to electrically conductive regions made in the grooves 46 and 47 provide an electrical power supply for the cathode 40 via the skid 43 in a manner similar to that described regarding the arrangement represented in Figures 1 and 2. A connection 52 is made to the anode 39.

The carriage 41 also supports, diametrically opposite to the cathode 40, a series of X-radiation detectors 53; the crystals being positioned between the collimators 54, 55, etc. mounted on the carriage. The X-radiation detectors are placed on the platform facing the cathode 40 and level with the anode 39. A flat annular collimator 56 is positioned to collimate the X-radiation in a flat strip projected through the body of the patient and penetrating again into the envelope of the tube on the opposite side to strike the detectors. The pair of paddles such as those described with regard to Figure 2 (on which a paddle was represented as 27)

is supported by the carriage 41 on a vertical upright, but these components are not represented in Figure 3. The arrangement of Figure 3 represents a single source and a single detector array. If required, several cathode and detector array systems can be mounted on the carriage 41 at regular angular intervals.

The way the tube operates is as follows. The cathode 40 is heated to emit electrons and these electrons are formed into a beam by the shape of the cathode and the anode-cathode potential difference and strike the anode to produce an X-radiation beam which is collimated in a plane 57 which is directed from one edge to the other of the ring formed by the anode 39, passing through the window 37, to the detectors 53. By making the carriage rotate, the source of the electron beam, as well as the point of impact on the anode, is displaced around the annular anode and so the mean direction of the X-ray beam rotates around the axis 42, the detectors 53 remaining facing the cathode 40 and in a position to receive the radiation originating from the anode. It is obvious that different variants of cathode-anode arrangements are possible, such as a stationary annular impact cathode with a primary cathode driven to rotate beneath it. In another embodiment, not represented, a complete X-radiation generator (that is, a cathode and a small anode) can be placed inside the emptied envelope on the carriage and excited via conductive regions of the grooves 46, 47, as described above for the cathode. The envelope can even be emptied in this arrangement, although, if necessary, the generator on the platform could be enclosed in an emptied and sealed vessel. The emptied envelope would reduce arc striking on moving contacts.

The anode 39 can be cooled if required, for example by the circulation of a coolant. The part 37 can be made of copper of a chosen thickness to act as a filter.

Figure 4 represents an appliance, comprising a tube 32 as described with reference to Figure 3, for examining a body 58. The axis 42 of Figure 3 is represented in Figure 4, and the reference 58 in Figure 3 indicates the position of a part of a body undergoing examination. The body 58 can be a human body or any other object, such as a cast part, to be examined. The tube 32 is mounted on the appliance as represented in such a way that the axis 42 is horizontal. In the preferred embodiment illustrated in Figure 4, the tube is in the form of a hollow torus surrounding the axis 42 and in which the carriage 41 supporting the cathode 40 and the detector array 53 can rotate to direct the radiation beyond the axis 42 in different directions in the plane 57 and to detect such a radiation after passage through a flat section of a body such as 58.

The appliance of Figure 4 comprises a frame 60 which supports the tube 32 and also a table 61 which can be inclined by means of a lead screw mechanism 62 of known type. The table 61 can also be driven longitudinally to the body of the patient 58 so that a required part of the anatomy of the patient 58 can be placed in the plane of the X-radiation produced by the tube 32. The longitudinal displacement is provoked by a second lead screw mechanism 63; the table 61 being able to be displaced by sliding relative to the frame 60. The patient is positioned on a deck 64 which is removably fixed to the table 61; the patient being fixed on the deck by means such as a strap 65, and a packing material 66, with absorption characteristics similar to the body of the patient 58, is introduced into the spaces between the body 58 and the deck, at least in the region to be irradiated.

The tube 32 is, in this example, of the continuously pumped type and is linked by the coupling 38 to a vacuum pump system, a part of which is represented as 67. Appropriate pump systems for emptying a tube

envelope of approximately 2 metres from one edge to the other and with a section of 0.2 x 0.2 metres will be easy to find.

The appliance described forms an X-ray examining appliance which has a simpler form than such an appliance comprising a discrete X-ray generator tube that can be displaced on a frame by a combination of reciprocal and rotational movements. There are no moving parts external to the tube 32, the movement of the internal parts being electrically controlled by mutual induction between cooperating parts 48 and 49 (Figure 3). The major connections to the tube 32, such as 50, 51 and 52, can be fixed and close to the floor of the frame as represented. The moving parts of the tube are displaced in the vacuum and can thus be displaced rapidly without resistance from excessive air, in particular if an X-ray examination needs to be performed rapidly enough to "immobilize" a moving part of the body.

The permanent linking of the detectors and of the source increases the accuracy of the radiation measurements. In plain language, the radiation measurements have to be transmitted from detectors being displaced, and this can be obtained by using one of many known techniques, comprising opto-electronic transducers and capacitive systems or other systems without electrical contact. Since the tube can be continuously pumped, it can also be able to be dismantled to allow the cathode or other components to be replaced. Furthermore, there is no need to use components that are degassed to a high degree, as with permanently sealed tubes.

Plastic materials known to have a low vapour pressure can be used in producing a continuously pumped tube form while the cooling means are reduced by the relatively large anode that is available.

Although a toroidal tube has been represented, a partially toroidal tube can also be used with a reduced movement of a curved platform, if that is preferred, and is encompassed by the invention. More than one cathode or electron beam can be used to allow an examination in several planes at a time with appropriate detectors.

Reference is now made to Figure 5 which represents, in a view similar to Figure 2, another tube that is similar to that represented in Figure 2, but uses an anode that is transparent to the X-rays 68 instead of the anode 2, 12 of Figure 2. The other components of Figure 5 that are common to Figure 2 are identified by the same reference numerals, and it will be observed that some of the components take slightly different forms and/or are positioned in different places from those represented in Figure 2 in order to house the different anode structure.

In Figure 5, the transmissive anode 68 comprises a thin ring positioned in and supported by a support ring 69. The support ring 69 is itself supported by an element 70 supported by the part 7 of the envelope of the tube. The carriage 17 supports the short cathode 16 on the rails 13 and 14 which are vertically offset from one another and supported by the part 7 of the tube. It will be noted that one of the cooperating parts 20 of the induction-driving unit 20, 21 is produced in a single piece with the carriage 17.

Also represented in Figure 5, there is a prolonged part of the part 7 of the tube which is hermetically fixed such as at 71 to a closure plug 72 through which pass electrical wires such as 22 which are sealed in a known manner. It will be understood that the extension and the plug do not extend all around the tube 1, but are provided only in an angular region of the latter.

Figure 6 represents, again in a view similar to Figure 2 and using the same reference numerals where appropriate, another embodiment of the invention. In the case of Figure 6, a fixed secondary electron emitting cathode 73 of annular form is positioned under the anode 2, 12; the cathode 73 being thin and supported by a support ring 74 and support uprights 75, the latter being fixed to the part 7 of the envelope of the tube. Positioned under the secondary cathode 73 there is a primary cathode 76, the latter being supported for the purpose of rotation in an annular bearing 77, the rotational driving force being imparted by the inductively cooperating elements 20, 21, as previously. The primary cathode 76 produces a primary electron beam which is directed towards the secondary cathode 73 and is displaced all around by virtue of the rotational movement of the primary cathode 76.

It will be noted that, once again, a different arrangement of uprights such as 26 and of paddles such as 27 is provided, compared to the arrangement of Figure 2.

The cathode 73 is held at a high positive potential (for example 3 kV) relative to the primary cathode 76, which has a circular or radial strip form, the electron beam escaping therefrom striking the thin cathode 73 and provoking a sufficient temperature rise for a major emission of electrons such as the electron beam 29 which will have a cross-sectional form substantially identical to that of the cathode 76.

Figure 7 represents, again according to a view similar to Figure 2, another embodiment of a tube arrangement according to the invention. Here again, the features common to Figure 2 are identified by the same reference numerals. It will be noted that, in the arrangement of Figure 7, there is no cathode carriage. In its place, an annular cathode, indirectly heated, 78, is fixedly

positioned beneath the anode 2, 12. The cathode is heated by a heating coil 79 which also extends all around the tube and is positioned in the immediate vicinity of the cathode 78. The electrical connections for the heating coil 79 are represented as 80, with the connections passing through respective columns 81, 82 made of electrically insulating material. The columns 81 and 82 rise from the base of the terminal plug 72 and provide a support for the heating coil 79. The heating coil is also, naturally, supported at a certain number of other points around the tube and can be elastically mounted so that it does not separate from the cathode when it is heated. The cathode 78 is supported by a ring 83 of electrically insulating material, which is fixed to the internal wall of the part 7 of the envelope.

Positioned between the cathode 78 and the anode 2, 12, there is an annular screen 84 which is produced with a single aperture 85. The screen 84 thus prevents the electrons generated by the cathode 78 from reaching the anode 2, 12 except in the vicinity of the aperture 85. The screen 84 is mounted to rotate in an annular bearing 86 supported by the part 7 of the envelope, and it can be driven all around the interior of the tube by electromagnetic induction by means of the cooperating elements 20, 21 as previously. When the screen 84 rotates the aperture 85 is displaced all around between the cathode and the anode, effectively making the beam 29 be displaced around the anode. The form and the dimension of the aperture 85 are empirically determined according to the desired form of the electron beam, taking into account the anode/cathode potential, the speed at which the screen 84 must rotate and any potential applied to the screen 84 itself.

In a variant arrangement using an annular impact (secondary cathode) of the type described concerning Figure 6, the primary cathode for generating electrons

for an impact on the annular cathode is fixed in position in the tube and produced so as to extend annularly to the same extent as said impact cathode. A screen that can rotate, in which there is formed an aperture, and being generally similar to the screen 84 of Figure 7, is provided between the primary cathode and the impact cathode. In operation, the electrons originating from the primary cathode are controlled by the screen so that electrons emitted by the primary cathode form a beam which is displaced around the impact cathode.

The preceding embodiments all required the use of elements that can be displaced inside the envelope of the tube, for example the carriage 71 in Figures 2 and 5, the carriage 41 in Figure 3, the cathode 76 in Figure 6 and the screen 84 in Figure 7. An even faster displacement can be obtained if such displaceable elements are eliminated, and in the three embodiments that will now be described, no mechanical movement is needed. This enables the radiation to be displaced completely around a body in a time period of the order of 3 milliseconds.

Reference will now be made to Figure 8 which represents a view, again similar to Figure 2, of a tube arrangement that has no moving parts.

An electron beam is produced from an impact cathode 97 in response to the impact on the latter of a primary electron beam originating from a primary cathode 88 which can be an electron gun of simple form and with relatively low current consumption. In Figure 8, the impact cathode 87 is in the form of a flat ring of a tape of tantalum with a thickness of between 0.005 and 0.05 mm. This tape is mounted on a ring 89 which, in its turn, is supported by a bar 90 fixed to the part 7 of the envelope of the tube 1. For certain uses of the tube, the electronic emission from the tape 87 must

begin and cease rapidly. Tapes with a thickness of between 0.005 and 0.05 mm can achieve this, particularly if a direct heating is also applied to maintain the cathode tape just below its emission energy level.

The primary cathode 88 is one of a certain number, for example 2 to 32 and preferably between 8 and 20, of equidistant electron guns around the ring of the envelope 1. The position of another primary cathode is indicated as 91.

The connections to the primary cathode 88 and to the associated electrodes are provided through a terminal plug 72. Each primary cathode is preferably an emitter of electrons of conventional form, indirectly heated.

All the primary cathodes operate in parallel and a modulator is used to determine the primary cathode from which an emission is requested. The primary emitter is surrounded by a simple beam-forming electrode, such as a dish of known form with a potential that is appropriate to fashion the electrons emitted into a beam which can be directed onto chosen areas of the surface of the impact cathode ring 87 adjacent to the primary cathode. The beam is directed by deflection members indicated by way of example by a pair of appropriately placed electrostatic deflection plates 88a which are supported by means such as electrically insulating bars 90a. Electromagnetic deflection coils could be used as a variant. In this way, the beam originating from the primary cathode 88 can be directed in hops or continuously to any area along an arc of the impact cathode 87; the length of the arc being determined by the number of electron guns used. The impact of the primary electron beam on the impact cathode 87 causes the main beam to be produced, and so the main beam is displaced along the respective arc of the anode 2, 12 making the latter emit an X-radiation

from the successive points of the impact of the main electron beam on it.

In a preferred embodiment of the tube described hereinabove, an emission of X-rays is required from a series of 320 equidistant target surfaces around the anode 2, 12. Twenty electron guns such as 88 are spaced equidistantly around the envelope 1, each with appropriate deflection means, for example plates 88a. As represented, each gun, for example the gun 88, is associated with a neck on the envelope, although this may not be necessary if a sufficient deflection of the beam is possible with the gun inside the contour of the ring. The electron emission from each gun is controlled either by switching off or switching on its heating member, or by using a modulating electrode, or both together. By connecting the cathodes and modulators of twenty guns to an appropriate matrix of control conductors in a known manner, any gun can be actuated. If an electrostatic deflection is used, all the plates for each direction of deflection can be linked to common connections when the gun that is active has been chosen by the cathode matrix. The deflection is arranged to choose, for each gun, sixteen target faces on the target 2, 12. Appropriate deflection techniques are well known.

In another embodiment of the tube, the electron beams applied to the target surface 2 of the anode 12 are taken from unique and distinct cathodes. To return to the case of 320 target surfaces and 20 guns, each gun is combined with electromagnetic or electrostatic deflection members and with beam modulation members to obtain the control described previously for the electron beam. It is clear that each gun has an output level higher than the primary guns described hereinabove and an electromagnetic deflection would be preferable given the "hardness" of the beam subject to all the anode-cathode potential.

In the various embodiments described, each of the electron beam sources could be arranged with a view to separate mounting in the envelope 1. Thus, a gun and a deflection assembly similar to that of a television image tube could be hermetically fixed in a removable manner to the envelope in the required position. In this way, all the consumable parts of the tube could be made replaceable at the same position thus reducing the servicing cost.

Figure 9 represents, in a view similar to Figure 2, another embodiment of a tube arrangement, according to an example of the invention, which does not require moving parts. In this case, the cathode comprises a cold cathode arrangement with multiple staged positions, annular, in which a cold cathode discharge is made to progress sequentially all around under the anode 2, 12 under the influence of appropriately excited control electrodes in a way similar to the operation of the counter tube known by the name of "Dekatron".

A reference, or starting cathode 92 is the first of a ring of guidance and cathode electrodes positioned under the anode 2, 12. The next cathode electrode in the sequence is represented as 93; two guidance electrodes, such as 94 and 95, being positioned between each pair of cathode electrodes and being excited in succession, in a known manner, to transfer the discharge that exists between a cathode and the anode to the space between the anode and the next adjacent cathode in the clockwise direction. In plain language, two guidance electrodes at least are necessary to ensure that the discharge progresses in hops in the planned direction, but more guidance electrodes could be used if necessary. All of the guidance electrodes such as 94 are connected in parallel, as are all the guidance electrodes such as 95. Furthermore, all the

cathode electrodes such as 94 (except the starting cathode 92) are connected in parallel; four conductors, represented in a beam 96 thus being necessary to pass through the terminal plug 72 in order to excite these electrodes.

Conveniently, the cathode electrodes and the guidance electrodes are supported in a ring 97 of electrically insulating material which is produced with ridges and/or depressions between each pair of electrodes to extend the electrical leakage line between them. The ring 97 is fixed to the wall of the part 7 of the tube.

In operation, a discharge is begun between the cold cathode 92 and the anode 2, 12 to produce electrons that are supposed to strike the target 2 and generate X-rays that are projected through the body of a patient as described hereinabove. Appropriate electrical control pulses are then applied to the guidance electrodes 94 and 95, in that order, to make the discharge be displaced in rotation and transfer it to the cathode 93. The point at which the electrons strike the target 2 is consequently displaced by the rotation of the discharge and thus the direction in which the X-rays pass through the body of the patient is modified.

Figure 10 represents, again in a view similar to Figure 2, another embodiment of the invention in which no moving part is needed. In this case, the cathode comprises a flat ring 98 of tungsten or other appropriate material. In this example, the ring 98 is heated directly to make it emit electrons although a configuration with indirect heating could be used, if required.

In operation, a potential is maintained between the anode 12 and the cathode 98 to extract an appropriate beam of electrons 29 under the action of an accelerating electrical field so as to make the

electrons bombard the target 2 and generate an X-radiation. Although, for given suitable power supply and cooling arrangements, it may be possible to make all the target 2 generate X-rays at an instant, the information flow speed needed to process simultaneous readings of, for example, a thousand detectors or more spaced around the position of the object would not be cost effective.

Consequently, the electron beam 29 is confined, at any instant, to a small region of the target 2 and is displaced around the tube to make the X-radiation pass through the body of a patient in different directions in turn.

In one form of the tube, a modulator 99 of openwork plates or wires, forming modulating elements, is inserted between the cathode 98 and the anode 12. In operation, the modulator is polarized with an electrical potential to prevent the electrons reaching the anode, except in the position from where the exploration beam is to emanate, the number of modulating elements being determined by the number of angular directions from which the body must be irradiated. Typically, approximately 500 modulating elements are necessary. Typically, the polarization potential is 3 kV negative relative to the cathode and the beam is displaced around the tube in approximately 3 milliseconds to reduce the effect of any deliberate or involuntary movement that a patient may make. It would be difficult and tiresome to make individual polarization connections through the envelope to actuate the modulating elements respectively. Consequently, a control circuit is provided inside the tube and connected to the modulating elements, and only input control conductors, of which there are fewer than the modulating elements and which can be selectively excited according to a multiple-level code to indicate the necessary modulating element, pass through the

envelope 11. The control circuit is indicated as 100 in Figure 10 and an appropriate screen, for example made of lead, is represented as 101. The screen 101 prevents the X-radiation from affecting the circuit's semiconductor devices. The control conductors are indicated as 102. They penetrate into the envelope 1 via the terminal plug 72 and extend around the envelope under the screen 101.

Figure 11 represents, in block diagram form, a control circuit for selectively exciting the modulating elements 99 one at a time. The excitation can be performed in regular succession so that the electron beam 29 progresses in hops around the tube at a uniform speed, or as a variant, the excitation can be performed in a pseudo-random order, said order obviously being known and predetermined.

Positioned outside the tube, there are nine switching circuits 103-111. Each receives respective power supplies of 0 V and -3 kV and has a respective pair of output conductors 112-120 which form together with the control conductors 102 of Figure 10. Each switching circuit is controlled by a binary logic input signal taken, for example, from the respective stages of a 9-stage binary counter 121 controlled by clock pulses in a known manner and the arrangement is such that when a switching circuit is supplied at its logic input with a binary "1", the left-hand conductor of its two output conductors is supplied with 0 V and the right-hand conductor with -3 kV. Moreover, on reception of a binary "0" at its logic input, a switching circuit acts to supply its left-hand output conductor with -3 kV and its right-hand output conductor with 0 V. Thus, in response to a particular binary number generated by the counter 121, a particular configuration of potentials is established on the nine pairs of output conductors.

The output conductors 112-120 constitute the control conductors 102 as mentioned above and are connected through the terminal plug 72 of the tube 1 in a known manner and extend around the tube under the lead shielding 101. Each element of the modulating array is connected to the conductors 102 so that only a configuration of potentials, established on the conductors as described hereinabove, eliminates the suppression potential -3 kV which is usually applied thereto. Each element is connected to only one of each pair of conductors and is connected thereto via semiconductor diodes so that only when all of the nine conductors to which it is connected are supplied with 0 V is the suppression potential of -3 kV suppressed from this element.

In the example represented, the binary counter 121 is assumed to apply the binary digits 1,1,0,0,0,0,0,0,0 to the switching circuits 103-111 respectively. Thus, the potential configuration on the conductors 102 is, as represented in the figure, 0,-3;0,-3;-3,0;-3,0;-3,0;-3,0;-3,0;-3,0; and -3,0. Thus, only a combination of one of each of the nine pairs of control conductors gives 0 on all the conductors in the combination. The connections for this combination are represented in the figure, the latter being for the $r^{th}$ modulating element 99r and thus all the components have as the suffix the letter "r".

The cathodes of the nine diodes 122r to 130r are connected to the respective control conductors 102 as represented; the anodes of the diodes being connected together and the common connection being linked via a resistor 131r to a conductor 132 which is common to all the elements and is still at 0 V. Said common connection is also coupled to the respective modulator or element 99r. In plain language, if all of the cathodes of the diodes 122r to 131r are at 0 V, as they are in this case, there is no voltage established at

the terminals of the resistor 131r and so there is no suppression potential applied to the modulating element 99r. The electron beam 29 can thus strike the target 2 in the position corresponding to the modulating element 99r. It is also clear that, if the cathode of any one or several of the diodes 112r to 130r is linked to a control conductor to which -3 kV is applied, then a current can circulate through the resistor 131r, establishing a potential at the terminals which provokes the application of a suppression potential to the element 99r.

Thus, at any instant, only an element 99r will have no suppression potential; the real element concerned being chosen by the binary number delivered by the counter 121. It will be understood that each element is linked to a respective combination of the control conductors 102; there is a connection from each element to one of each pair of said conductors as described.

In all the embodiments which do not require real movement of mechanical components around the tube, a problem arises as to the collimation of the X-radiation emerging from different locations on the target 2 in a fan-shaped spread of the required angle (for example, 20°). Such a collimation can be performed by means of a fixed ring of collimators positioned adjacent to the output surface of the collimating ring 4; the collimators in said fixed ring being inclined in the irradiation plane. As a variant, displaceable collimating rings can be used, provided that the latter are accurately synchronized on the movement of the region emitting the X-radiation.

In all the cases where the radiation has been represented as being propagated through the body of a patient along an inclined plane, it is desirable for the plane to be inclined only by approximately 1° to 3°

relative to the flat plane that would ideally be irradiated.

CLAIMS

1. X-ray tube arrangement, characterized in that it comprises a target sending elongate X-rays which is curved around an axis and subtends a major angle on said axis, a source of at least one electron beam, means for making said beam strike a region of said target so as to make the latter emit X-rays in the general direction of said axis, and means for making the electron beams originate from source positions distributed over the length of said target to provoke an emission of X-rays, in said general direction, from different regions along said target.

2. Arrangement according to Claim 1, characterized in that said target is made to practically surround said axis.

3. Arrangement according to one or other of Claims 1 or 2, characterized in that it comprises a carriage capable of being displaced in said tube and along said target, said carriage supporting at least one component of said electron beam source.

4. Arrangement according to Claim 3, characterized in that it comprises a cathode mounted on said carriage and positioned to project electrons directly onto a region of said target.

5. Arrangement according to Claim 4, characterized in that said cathode comprises a substantially flat rolled tungsten element.

6. Arrangement according to Claim 3, characterized in that it comprises a primary electron beam source, supported by said carriage, and a secondary cathode positioned adjacent to and practically of the same extent as said target, said source of said primary electron beam being positioned so that said beam

strikes the secondary cathode, making the secondary cathode emit other electrons towards the target, said carriage displacing said primary electron beam relative to the secondary cathode so that said other electrons are emitted towards said target successively from different regions of the secondary cathode.

7. Arrangement according to one of Claims 1 to 3, characterized in that said target comprises a target that is transparent to X-rays.

8. Arrangement according to one or other of Claims 1 or 2, characterized in that it comprises an elongate cathode, substantially of the same extent as said target and a disc that can rotate, positioned between said cathode and said target, said disc being made with an aperture in a region of the latter through which an electron beam can pass from said cathode to said target; means being provided to rotate said disc so that said aperture successively assumes different positions relative to said cathode and to said target to displace said electron beam along said target.

9. Arrangement according to one or other of Claims 1 or 2, characterized in that it comprises a cathode positioned adjacent to and substantially of the same extent as said target, a source of a primary electron beam, means for electrically displacing said primary beam relative to said cathode to make electrons be emitted from successive regions of said cathode towards successive regions of said target.

10. Arrangement according to one or other of Claims 1 or 2, characterized in that said source comprises an assembly of cold-cathode discharge elements spaced apart over the length of said target and adjacent to the latter, and guidance means for making a discharge be displaced from one of said discharge elements to

another according to a predetermined succession so as to displace said discharge relative to said target.

11. Arrangement according to Claim 10, characterized in that said guidance means comprise at least two guidance electrodes, connected to respective conductors, positioned between each pair of said cathode elements and means for sequentially applying pulsed electrical potentials to said guidance electrodes.

12. Arrangement according to one or other of Claims 1 or 2, characterized in that it comprises a cathode element substantially of the same extent as said target and an assembly of modulating elements positioned between said cathode and said target, and selection means for selectively making said modulating elements allow an electron beam to circulate from said cathode to said target.

13. Arrangement according to Claim 12, characterized in that said selection means comprise a diode modulating circuit of the form represented in Figure 11.

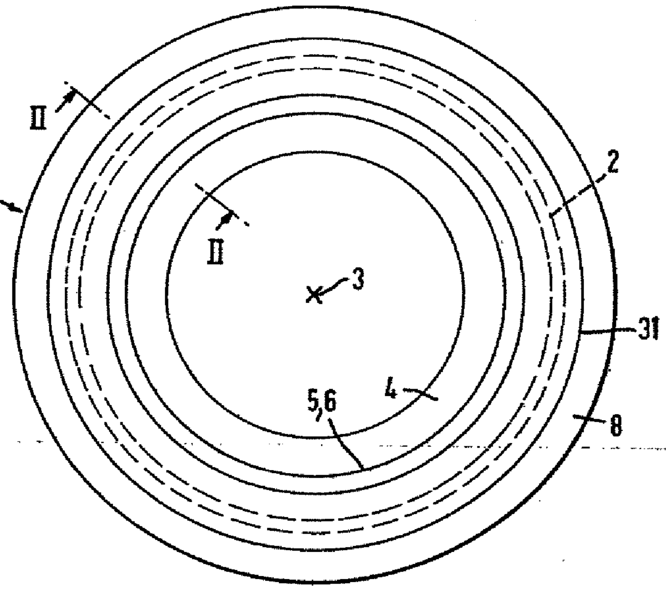


FIG.1

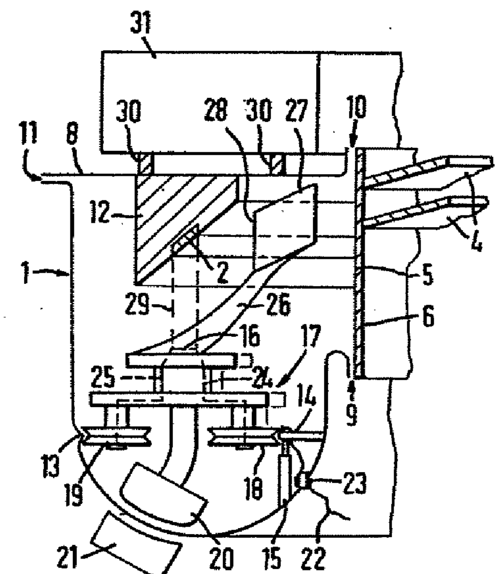


FIG.2

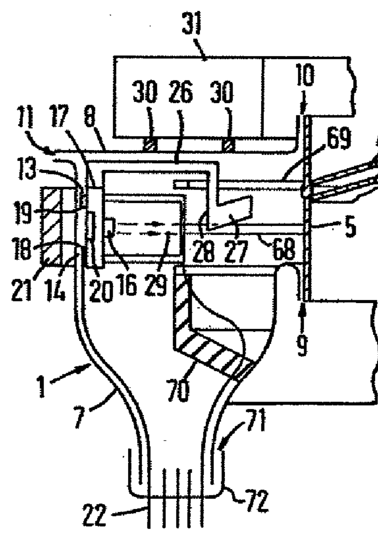


FIG.5

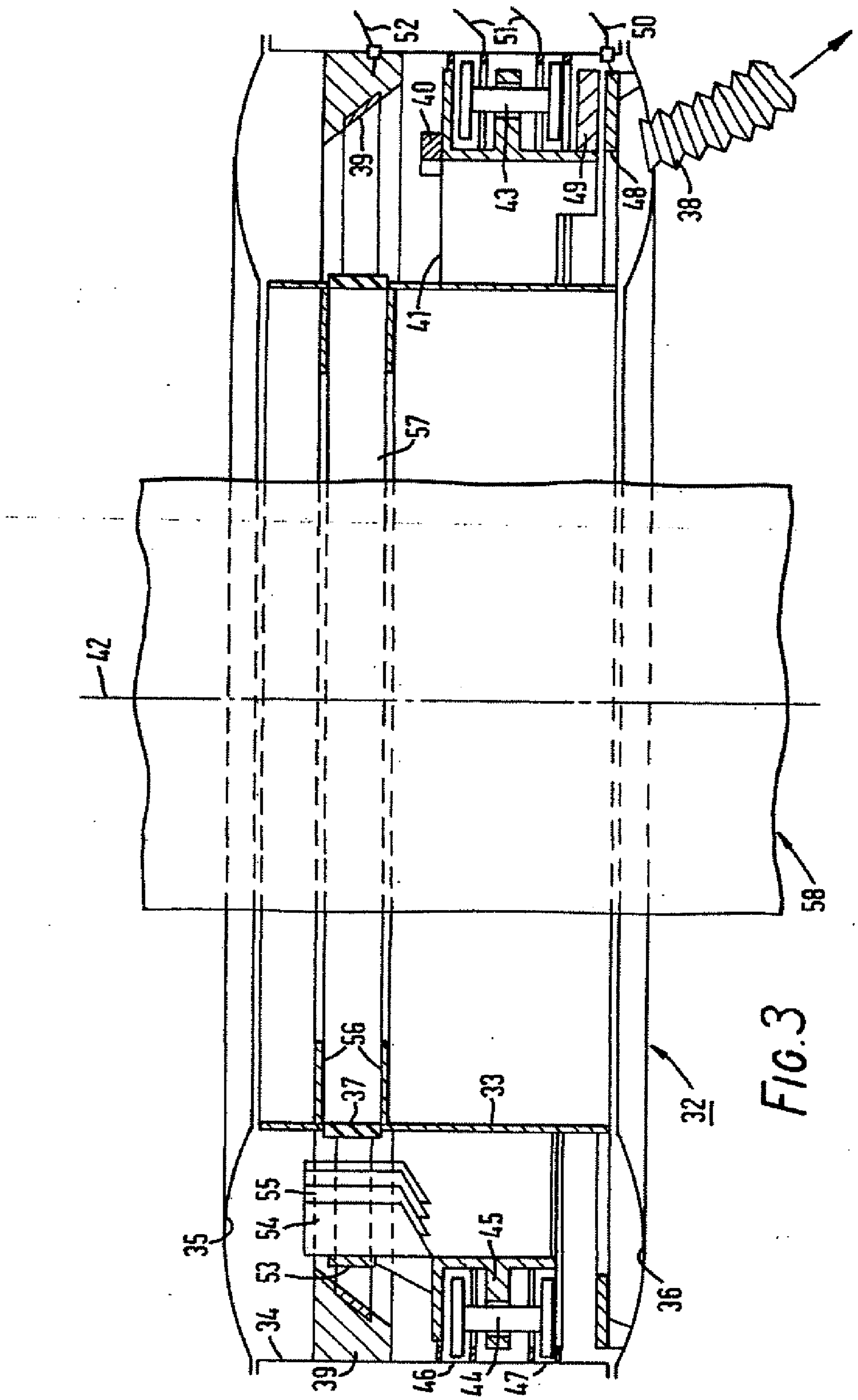
52
51
50
40
39
43
49
48
38
41
57
42
58
56
37
33
32
35
55
54
45
53
34
39
46
44
47
36

FIG. 3

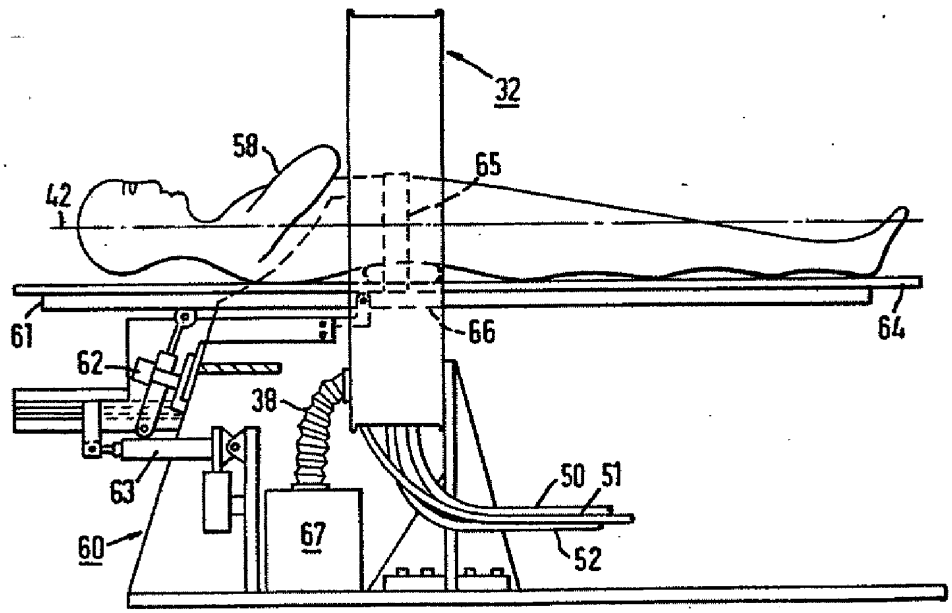


FIG.4

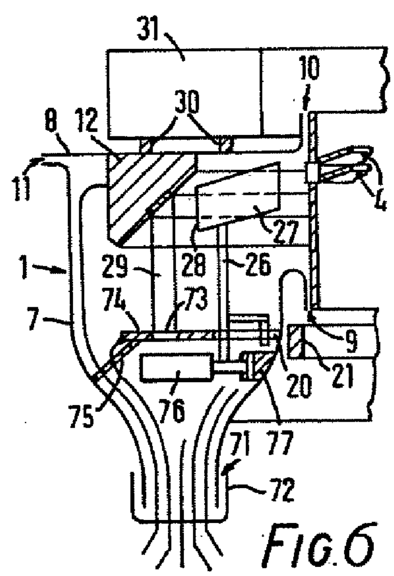


FIG.6

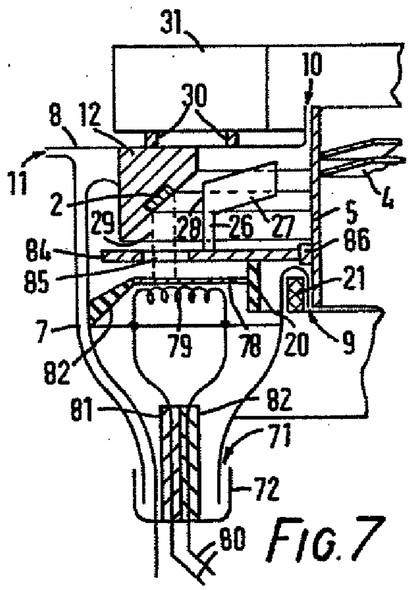


FIG.7

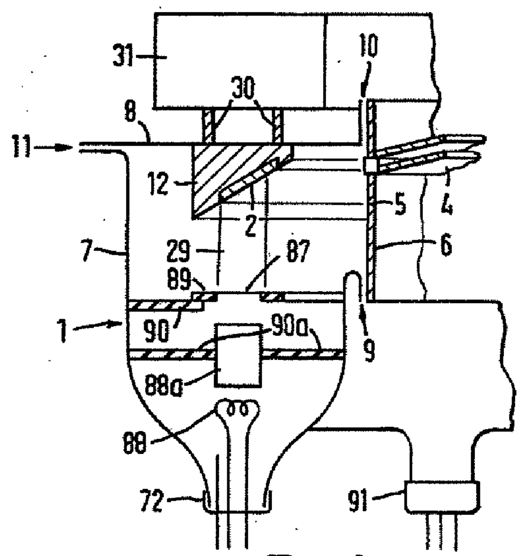


FIG. 8

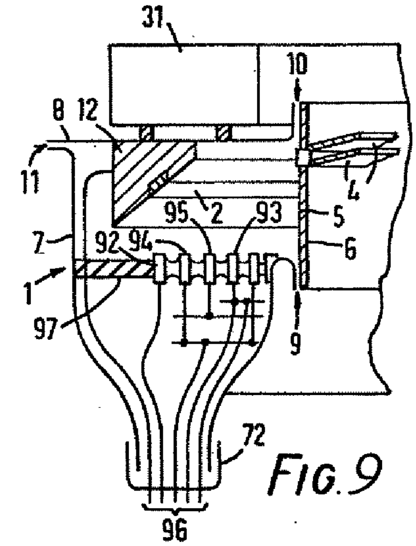


FIG. 9

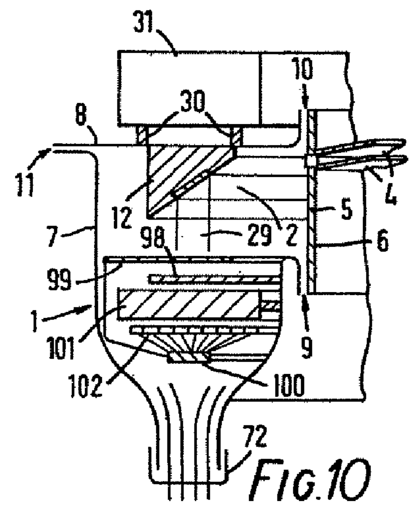


FIG. 10

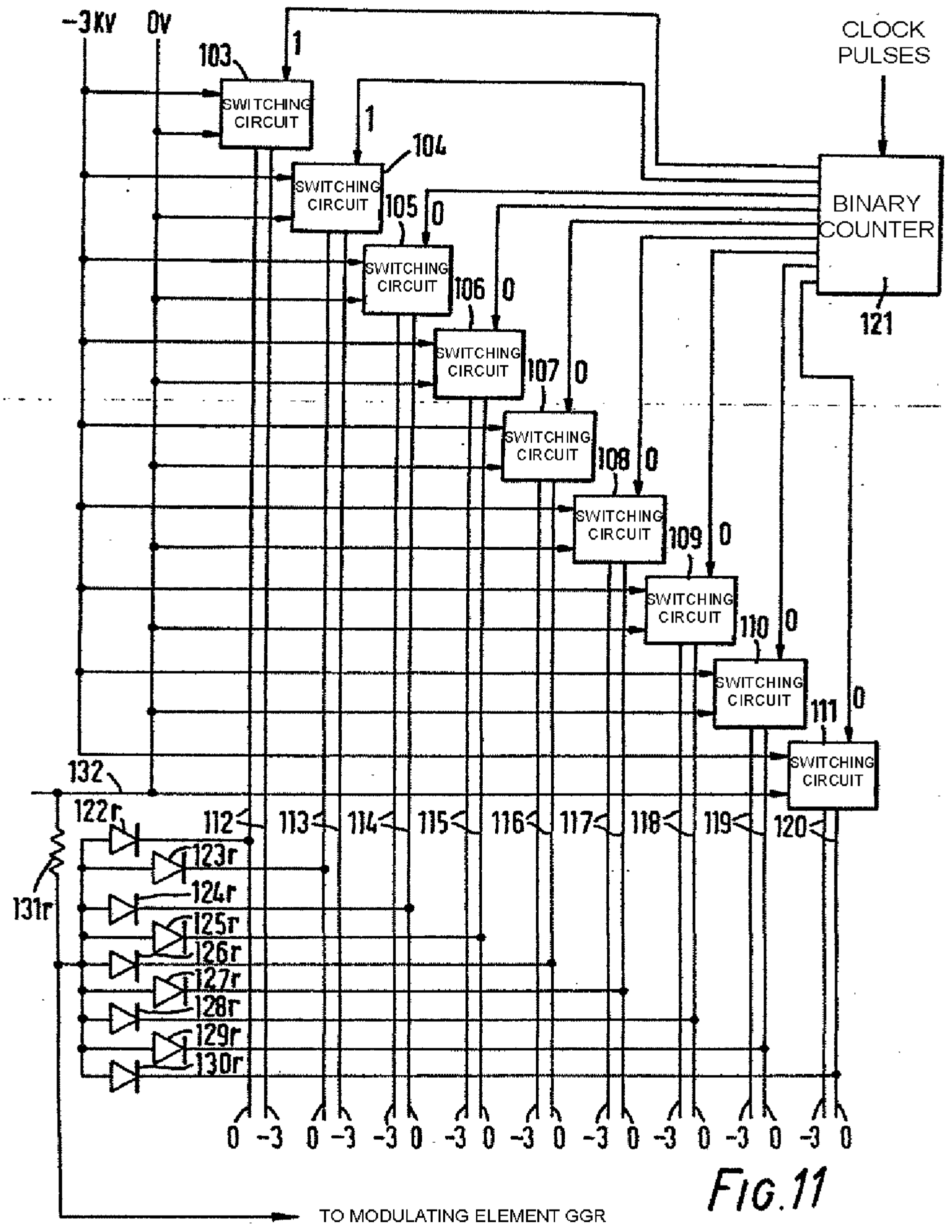
-3KV
0V
103
1
SWITCHING CIRCUIT
1
104
SWITCHING CIRCUIT
105
0
SWITCHING CIRCUIT
106
0
SWITCHING CIRCUIT
107
0
SWITCHING CIRCUIT
108
0
SWITCHING CIRCUIT
109
0
SWITCHING CIRCUIT
110
0
SWITCHING CIRCUIT
111
0
SWITCHING CIRCUIT
CLOCK PULSES
BINARY COUNTER
121
132
122r
123r
124r
125r
126r
127r
128r
129r
130r
131r
112
113
114
115
116
117
118
119
120
0 -3 0 -3 -3 0 -3 0 -3 0 -3 0 -3 0 -3 0 -3 0
TO MODULATING ELEMENT GGR

FIG.11